MIXTURE CHARACTERISTICS OF BUTON ROCK ASPHALT

MOHAMED H. ALI

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

ABSTRACT

The huge deposit of Buton Rock Asphalt (BRA) in Lawele of Buton Island, Indonesia, has not been utilized optimally. The less optimal usage was due to lack of knowledge on its characteristics. It is expected that there will be a shortage in petroleum bitumen, due to high price or limited sources of petroleum in the future. In this research, the bitumen used was penetration grade 80 /100 as control. Numerous bitumen tests were conducted in the laboratory to investigate the characteristic of BRA bitumen such as the penetration, softening point, and viscosity test. Only one aggregate gradation was considered under this investigation. An attempt was made to evaluate the mixture characteristics of BRA. The optimum bitumen content by using the Superpave mix design method were 6% , 6%, 6.5%, 7% for petroleum bitumen, BRA bitumen, 10% BRA granular and 15% BRA granular, respectively. Then by using Universal Testing Machine (UTM), the samples were tested for performance tests which were Indirect Tensile Stiffness Modulus Test and Dynamic Creep Test. The samples were tested at different temperatures of 30˚C, 40˚C, 50˚C using the Indirect Tensile Stiffness Modulus Test. Similarly, the samples were tested at 45˚C using Dynamic Creep Test. It was observed that the effectiveness of using BRA as granular showed better performance in the asphalt mixture. From the results, the use of 15% BRA granular showed the highest stiffness modulus and the highest permanent deformation resistance when compared with 10% of BRA granular and BRA bitumen. In addition, the use of 15% BRA granular showed the highest creep resistance.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The price of barrel crude oil has reached more than 100 dollars, and that caused a rise in the price of bitumen refinery too. For that reason many researchers had done investigations to find a solution for this problem and looking for another alternative of bitumen refinery. In this research, the use of Buton rock asphalt was investigated as a binder of asphalt pavement and alternative of refined bitumen. Buton rock was chosen because it has a large source which is about 300 million tons. It is the largest sources in the world compared to other natural asphalt resources. It is therefore needed to have further investigation on the use of Buton rocks as binder. For that reason, this research developed the technology of using Asbuton by investigating the mixture characteristics in relation to the asphalt pavement performance. The investigation was also conducted to petroleum bitumen as a control, and to the blend of Buton rock asphalt and petroleum bitumen in various ratios to establish the trend of the changing ratio effect on the asphalt blend characteristics. Using this trend, the optimum ratio was found to produce a better quality of asphalt.

Buton rock asphalt is natural asphalt from Buton Island in Southeast Sulawesi Province in Indonesia. There were two types of natural asphalts available in Buton Island of Indonesia namely rock asphalt located in Kabungka area consisted mainly as hard asphalt and the softer natural asphalt in Lawele area. The deposit amount of Lawele asphalt was around 62.5 million ton with asphalt content on the average of 21.8% and in Kabungka about 100,000,000 tons (Alberta, 1989). It was unfortunate that the utilization of that type of bitumen as road making material has not been optimized yet since some difficulties still arises on its exploration and use.

1.2 Problem Statement

In 2008, the price of crude oil reached 150 USD per barrel, the most expensive it has ever had. It caused the price of refined bitumen got the most expensive state too. Because of that, to expect the same cases in the future, it is realistic to look for other alternative of refined bitumen. In this research, all tests were conducted to investigate the viability of Buton rock asphalt mixture characteristic and Buton rock asphalt bitumen to use it as a binder in asphalt pavement and as other alternative of refined bitumen.

1.3 Objectives of the Study

The primary objective of this study was to investigate the viability of mixture characteristic of Buton rock asphalt (BRA) and that could be achieved by:

i. Analyzing BRA bitumen characteristics
ii. Investigating the performance characteristics of BRA mixture
iii. Measuring the effectiveness of using BRA as granular and pure bitumen

1.4 Scope of Study

The scope of this study was Buton rock asphalt or (Asbuton). It is natural asphalt which extracted from Buton Island located in Southeast Sluawesi province in Indonesia. There were two types of natural asphalts available in Buton Island of Indonesia namely rock asphalt located in Kabungka area consisted mainly as hard asphalt and the softer natural asphalt in Lawele area. In this study, soft asphalt was used from Lawele because the bitumen characteristics relatively same with petroleum bitumen for asphaltic binder so could be used as the binder with minimum preprocessing.

For others materials such as petroleum bitumen and aggregates were found from sources provided in Malaysia. There were no on-site investigations but all the tests were conducted in highway laboratory.

The important thing need to know the performance test between the mixtures and investigation to ensure the mixture to get a good mix has a high quality. Two types of performance test were conducted which were Indirect Tensile Stiffness Modulus and Dynamic Creep Test. Figure 1.1 illustrates of BRA use as binder in asphalt mixture (Pt Buton Asphalt Indonesia).

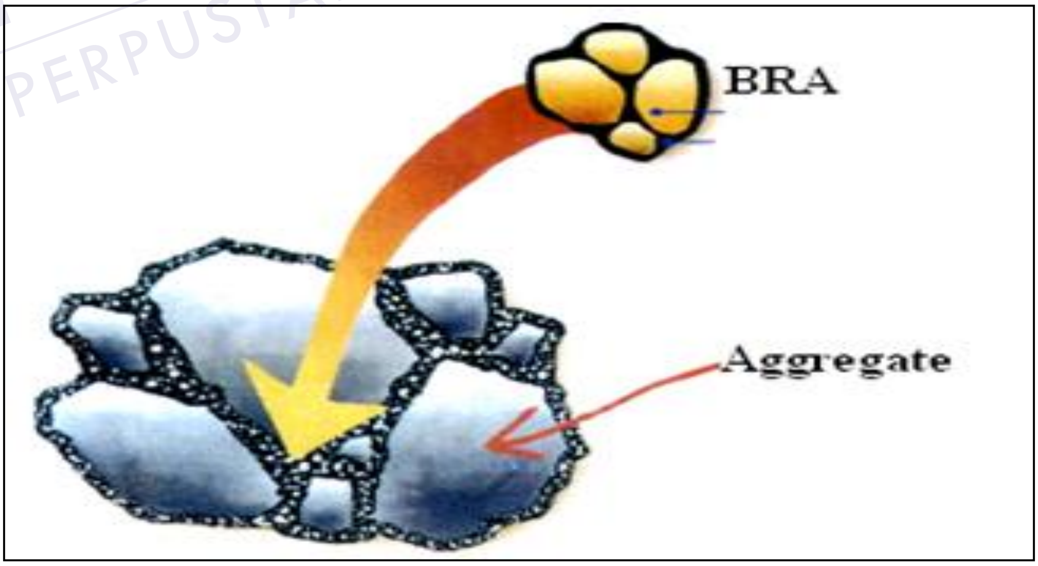

Figure 1.1: Using of Buton rock asphalt as binder (after Pt Buton Asphalt Indonesia)

1.5 Significance of the Study

As a result of increasing the petroleum price, many countries started to find other material which can be used instead of the bitumen which was used in the road construction. Although there was no evidence about the of Buton rock asphalt on the road, the finding of this study was important to understand the Buton rock asphalt itself. This research is essential to explore the main characteristic of Buton rock asphalt and its behavior under simulated traffic loads. Buton rock asphalt is cheap and available in large quantity and has similar characteristic with bitumen. It has the potential to be used as binder in road pavement.

1.6 Thesis Organization

This thesis is divided into five chapters. Chapter 1 provides a general overview of the study. Literature review on Buton rock asphalt and discussion is presented in Chapter 2. The experiments set up and the techniques used are explained in Chapter 3. All the experiments data and results are presented in Chapter 4 together with the finding and discussions about the results. Finally, Chapter 5 describe the conclusion and recommendations for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Due to the large increment in the costs of petroleum bitumen and limited resource, a lot of discussion was made on this crisis looking for other alternative of refined bitumen. "Rock asphalt exists in large quantities in Buton Island, Indonesia, and until late 1990s was used extensively in its natural state as a surfacing layer for existing road pavements" (Rudy, *et al* 2003). Rock asphalt deposits exist in large quantities in Buton Island, South-East Sulawesi, Indonesia, and it is named locally as Aspal Buton or ASBUTON. Since the deposits are widely variable in both composition and properties, then the production of a consistently uniform material, whose performance can be predicted with reasonable confidence is really difficult (McElvaney, 1986). There are two types of natural asphalts available in Buton Island of Indonesia namely rock asphalt located in Kabungka area consisted mainly as hard asphalt and the softer natural asphalt in Lawele area. The deposit amount of Lawele asphalt is around 62.5 million tons with asphalt content on the average of 21.8% (Alberta, 1989).

2.2 Materials characteristics

2.2.1 Bitumen

Bitumen is manufactured from crude oil. It is well-known that crude oil originates from the remains of marine organism and vegetables matter deposited with mud and fragments of rock on the ocean bed (Read, 2003a). Bituminous materials or asphalt are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost. Bituminous materials consists of bitumen which is a black or dark colored solid or viscous cementations substances consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Bitumen will be dissolved in petroleum oils unlike tar (Mathew and Krishna, 2007).

Bitumen is a viscoelastic material with suitable mechanical/rheological properties for traditional paving and roofing applications because of their good adhesion properties to aggregates (Uranga, 2008). However, the increase in traffic load requires improving the mechanical properties of conventional asphalt mixtures. Bitumen is particularly temperature sensitive. It is also prone to permanent deformation under an applied load, with the rate of deformation dependent on the bitumen grade, asphalt composition, ambient temperature, and level of stress and load time (Robinson, 2004). The important properties of bitumen are as follow:

1) Viscosity: The viscosity of bitumen determined how the material will behave at given temperature and over a temperature range. The basic unit of viscosity is Pascal second (Pa.s). The absolute or dynamic viscosity of bitumen is the shear stress applied to a sample of bitumen in Pascal divided by the shear rate per second (Read, 2003b).

2) Cohesion: The cohesion strength of penetration grade bitumen is characterized by low temperature ductility.

3) Adhesion: Bitumen adheres well to a vast majority either in the initial coating of the aggregate in the absence of water. Whenever water is present, difficulties often arise either in an initial coating of the aggregate or maintaining an adequate bond between the bitumen and aggregate.

4) Temperature susceptibility: Bitumen portray thermoplastic properties, they become softer when heated and harder when cooled.

5) Stiffness: At high temperature or long loading times bitumen behaves as viscous liquids while at low temperatures or short loading times, it behaves as elastic solids.

2.2.2 BUTON NATURAL ASPHALT

Buton rock asphalt is natural asphalt from Buton Island in Southeast Sulawesi Province in Indonesia. Buton Island has been known as natural asphalt sources. Dutch geologist, Hetzel, found the natural asphalt deposit in Buton Island in 1920. He completed the natural asphalt deposit map of Buton in 1936. The Directorate of Inventory and Mineral Resources in Bandung - Indonesia shows that natural asphalt in Buton Island located in many places, such as Kabungka, Lawele, Winto, Wariti, Waisiu, Rongi and Ereke areas. The exact deposit of the natural asphalt resources has not been known clearly. PT. Sarana Karya, a state own asphalt mining company, estimates that sources of the Buton rock asphalt is about 300,000,000 tons, spreaded in Kabungka about 60,000,000 tons, in Lawele about 100,000,000 tons, in Winto about 3,200,000 tons, in Wariti about 600,000 tons, in Waisiu about 100.000 tons. However, only two locations have been exploited. Those are Kabungka (since 1980) and Lawele since 2003. Nevertheless, the exploitation is still very limited. (Utilization and Improvement Team of Asbuton, 1999).

The using of Buton rock asphalt in asphalt pavement has not optimal used because its characteristics has not been known completely. Natural asphalt from Kabungka contains hard asphalt and from Lawele contains soft asphalt. (Tumewu, *et al* 2005).Figure 2.1and 2.2 illustrate the location of Buton Island in Indonesia and the place of available Buton rock respectively.

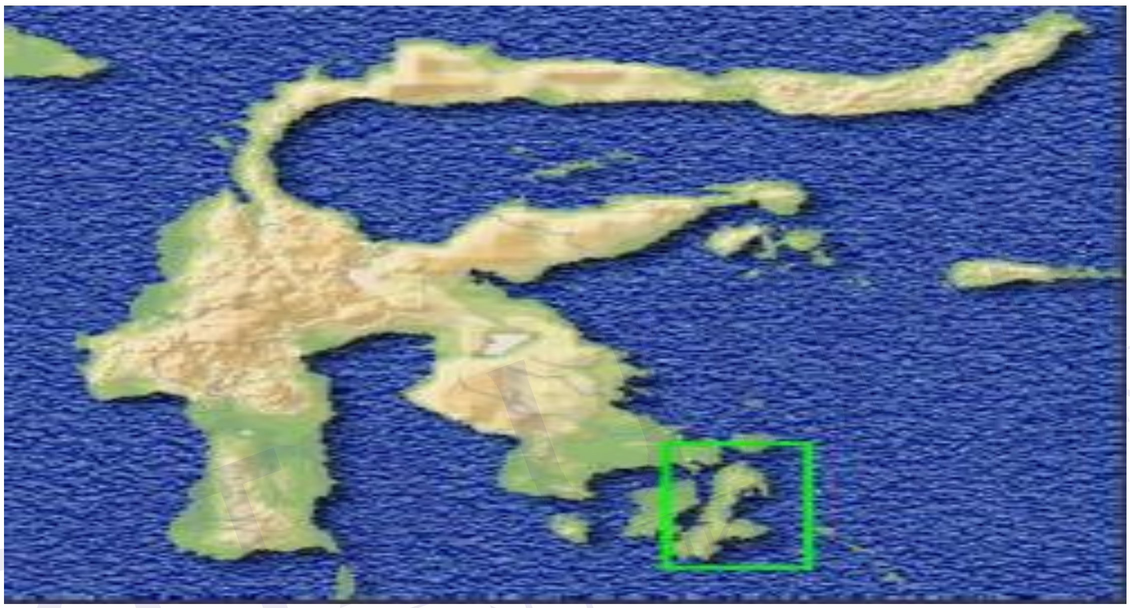

Figure 2.1: The location of Buton island in Indonesia (after Pt Buton Asphalt Indonesia, 2003)

Figure 2.2: The location of available Buton rock asphalt at Buton island (after Pt Buton Asphalt Indonesia, 2003)

2.2.2.1 Mining and Extracting

The crude asphalt is mined using trench-digging machines. When excavated, the crude asphalt is loaded into trolley buckets, which are pulled by cable along a trestle and dumped into open topped vessels or separation stills for extracting.

Extraction process is a process of dissolving, whereas Buton asphalt rocks in certain shapes are dissolved in proper solvent, then the mixture is separated or re-taken using certain technology until asphalt materials remain and are further processed as according to market specification demand

Separation of solvent entity from solid materials is perfectly done using vibrated thin-film evaporator. Solid materials, after being specified, can be used for Asbuton products such as Buton Epure, Instant Bitumen, while the solvent leaching entity is recycled and used for next extraction process.

Present study shows that using an extraction process to produce pure bitumen from Asbuton is technically viable option. Counter cross flow solvent used as an agent to drive simple liquid-solid separation in extraction process is proved capable of producing various grades of bitumen to meet market demand. One of the advantages using this process is its insensitivity to feed various size of Asbuton feed stock, so that the process can avoid unnecessary requirement of extensive crushing and blending equipments to provide a specific feed stock. Another advantage is its product flexibility: by using desolventizer and dust disintegrator and by adjusting distillation conditions, various grades of products can be produced for diverse market.

The extraction of Buton natural asphalt rocks is an essential process to make a high quality material to derive other high quality asphalt related products. For example, through high standard Marshall Test of Buton Epure, extraction process will guarantee its quality into product which is needed broadly in road or highway construction. Figures 2.3 and 2.4 show the mining operation in Lawele and Kabunga, respectively.

Figure2.3: Mining operation in LAWELE (after Pt Buton Asphalt Indonesia, 2003)

Figure2.4: Mining operation in KABUNGA (after Pt Buton Asphalt Indonesia, 2003)

2.2.2.2. Advantage of Asbuton

There are some advantages of the Asbuton for the purpose of asphalt mixture production. These advantages are as follows:

i. **Improvement In Mix Stability**

The “job mix” or the “design mix” as it is also sometimes called, refers to the ratio of bituminous binder to aggregates of varying sizes as outlined by the job’s specification. Because of the integration of dissimilar components, in this case, a hydrocarbon with stony matter, there exists the tendency for the entire mixture to lose its homogeneity, or breakdown. The inclusion of Asbuton to the mixture presents inorganic matter that is evenly distributed in such a way as to reduce the natural tendency of the mix to breakdown, or become prematurely unstable.

ii. Increased Stability at High Temperatures

Due to the hardness of Asbuton (possessing a penetration of between 0 and 5 PEN), its softening point is naturally higher (70ºC) than soluble bitumen; therefore, its tendency to react to imposed forces (heat, pressure) is deferred significantly. This augurs well for any design mix, since it is an indicator that an Asbuton paving would be resilient to extreme temperatures.

iii. Increased Strain Performance At Low Temperatures

Strain, being an engineering materials phenomenon defined by the elongation of a material as a ratio to its natural length due to applied tension, the ability of Asbuton-blended mix to resist cracking under low temperatures is yet another performance-related characteristic. This allows it to yield incomparable results over a wide spectrum of extreme conditions. Despite its hardness, Asbuton outperforms the strain resistance of refinery bitumen by 28% at –10ºC. Performance at low temperature, asphalt of Buton a unique naturally occurring bitumen binder for improving the performance of asphalt pavements in roads, airports, tunnels and similar heavy duty sites.

iv. Reduced Cracking

Pavements are subject to the harshest of conditions that include extreme temperatures, sharp temperature gradients, and heavy loads, promoting unwanted compression, shear and other mechanical drawbacks. Many of these manifest themselves as cracks in the surface, which are unsightly at best. The worst of these continue for such length as to eventually result in a total divorce of one part of the roadway from the other. As a consequence of improved mix stability, the incidence of these is either reduced or negated by the use of Asbuton.

v. Reduction In Surface Breakup

Being an amalgamation of mainly aggregate and polymer-based binders with optional or recommended additives, a pavement's entire section is always under a series of varying stresses. It is the occurrence of abrasion and the direct ultraviolet exposure that can result in loosening and eventual dispersion of the surface, for which, the higher quantities of martens promote binding capabilities and therefore suppresses the likeliness of surface breakup.

vi. Increased Resistance To Fatigue

As a result of its higher specific gravity (up to 40% more than conventional, straight-run bitumen), Asbuton is remarkably resistant to fatigue in several forms, including compression and shear. Its higher density encourages a reduced tendency for inorganic matter movement and hence, higher fatigue-resistance

vii. Reduced Maintenance Costs

The costs associated with downtime arising out of routine or remedial maintenance is a woe of even many a first class paving, which Asbuton is never purported to eradicate, but rather, reduce tremendously. Due to longitudinal shear, surface shear, daily positive and negative temperature gradients and other natural and subjective pressures, the asphalt's entire section is eventually compromised to result in failure that warrants routine maintenance, and sometimes unforeseen costs. The use of Asbuton automatically reduces the maintenance effort sometimes by as much as 70%, quite often making it an eventual lower-costing alternative that many other modifiers.

viii. Improved Skid-Resistance And Road Safety

This being the flagship of Asbuton characteristics, high speed and heavy duty users know of the virtue of anti-skid performance related to safety. Because better coatability is achieved in using a Asbuton binder over a soluble binder or other modified binder, the surface of the aggregate, as well as the force of cohesion between them, is more 'polish-resistant', allowing for a surface that yields better tire to asphalt traction, and thus, far less tendency to skid.

ix. Improved Ease Of Handling In Bad Weather Conditions

Low temperatures and rain always present a problem for the smooth and easy handling of many road-surfacing applications. For hot mix pavements, this is an increased issue since the preferred temperature of laying the asphalt lies within a reasonably close tolerance. Although bad weather conditions only serve to promote the counterproductive environment of cooling, the heat-retention properties of Asbuton tend to counteract the urgency of any undesirable cooling, making it easier to handle in bad weather as a result of the material staying in its loose, mixed form longer.

x. Ability To Be Mixed With Almost All Other Binders

As a testament to its affinity for binders, Asbuton can be mixed with all known polymers and polymer-related bituminous compounds. Being essentially a hydrocarbon that is chemically bound to interlocked inorganic matter, Asbuton resists the tendency for separation and sedimentation of other non-Asbuton binders, and this is what has enabled Asbuton to be used in 31 different countries around the world, each with equal success. In its native origin of Buton, it is blended with 180-200 penetration bitumen in measured proportions to produce a superior blend of 60-70 penetration Asbuton that is used on highways, airports and marine terminals. (Sino Prosper Indocarbon SPI).

2.2.3 Aggregate

Aggregate is major materials in building construction industry and has a large portion of an asphalt pavement. American Society Testing Materials (ASTM) defines aggregates as a granular material of mineral composition such as sand, gravel, crushed stone, shell, and slag used with a binding medium such as water, bitumen, Portland cement and lime to form compound materials such as asphalt concrete and Portland cement concrete. Aggregate is also used for base and sub-base courses for both flexible and rigid pavements.

Aggregate is generally naturally derived from mineral and can be either natural or sometimes have been further mechanically processed to be better suited for specific applications. The synthetic aggregates are also used in asphalt pavements and are most commonly blast furnace slag's from steel industry. The natural aggregates are generally extracted from larger rock formations through an open excavation quarry. It is divided into three geologic classification of rock, sedimentary, metamorphic, and igneous.

Three types of aggregates are crushed stone, sand and gravel. Crushed stone is mechanically crushed rocks or boulders. Most crushed stone is quarried from bedrock. Gravel is the product of the erosion of bedrock and surficial materials. Gravel can also be crushed, and that is actually recommended for its use in asphalt pavement or bases. Sand can be either the erosion of bedrock or be mechanically crushed. Sand is distinguished by its size, which according to ASTM C 125, Standard Terminology Relating to concrete and Concrete Aggregate, would be smaller than 4.75 mm but larger than 75 µm (Teong, 2007).

2.2.3.1 Aggregate Source

Aggregates can come from either natural or manufactured sources. Natural aggregates come from rock, of which there are three broad geological classifications (Teong, 2007).

i. Sedimentary rock. These can be sub-classified to calcareous and siliceous. These rocks were formed by the accumulation of sediments carried by water or wind (e.g., the remains of existing rock deposited on the bottom of an ocean or lake). Calcareous sedimentary rock is calcium derived (limestone, chalk, etc.), and siliceous is silica derived. The features of sedimentary rock structure are that it consists of layers. Sedimentary rock makes up about 70 percent of the crushed stone production.

ii. Metamorphic rock. Metamorphic rock was formed from either a sedimentary or igneous rock structure put under a tremendous amount of heat or pressure next change their mineral structure to be different from the original rock. Metamorphic rock makes up about 8% of the crushed stone production.

iii. Igneous rock. These can be classified into intrusive and extrusive rock. This rock was formed through the cooling and solidification of molten magma that erupted from earth. Extrusive igneous rock was formed by cooling on the earth’s surface and intrusive was formed originally below the earth’s surface. Igneous rock makes up about 22% of the crushed stone production.

2.3 Asphalt

Through the few last years, the use of asphalt in road building has gradually increased and reached its peak in 1979, it is concluded that the current annual worldwide consumption of asphalt is over 100 million tons (Tripathi, 2000).

Asphalt is a thermoplastic viscoelastic adhesive. It gradually softens and eventually become fluid when heated. It is characterized by its consistency at certain temperatures. Its relevant properties are its workability, strength, durability, imperviousness and adhesion. (Generally, the viscous properties of asphalt binder should be sufficiently fluid to permit it to be handled during construction and to coat and wet aggregate, viscous at high pavement temperatures so that it will not permanently deform under traffic and fluid at low temperatures to permit it to avoid fracture and cracks) (Richard and Bent, 2004).

The use of asphalt in road paving construction is a strong cement, readily adhesive, high waterproof, and durable. It is a plastic substance that imparts controllable flexibility to mixtures of mineral aggregates with which it is usually combined. It is because of these superior qualities that asphalt is so widely used in road construction (Tripathi, 2000).

The selection of the grade and type of asphalt were according to the type of construction and the climate of the area. However, the major problems with unmodified asphalt are the formation of wheel ruts by the repeated pressure exerted by vehicle tires at places such as heavily trafficked. Further, hot climates in Malaysia, the plastic qualities of asphalt can lead to permanent deformation (Nicholls, 1998).

2.3.1 Asphalt Concrete (Hot Mix Asphalt)

Asphalt that has been specially prepared for use in pavement by controlling its quality and consistency is called asphalt cement. Asphalt cement is ordinarily used in a (hot mix) pavement composition that also contains coarse and fine aggregate. This composition, also called asphalt concrete, is blended at high temperature, applied to the roadbed while still hot, and compacted with rollers to produce a smooth driving surface. The performance of asphalt pavements is largely the function of the asphalt concrete surface material (Tripathi, 2000).

The most important property needed in this research in the objective of asphalt concrete mix design process is stability or resistance to permanent deformation under the action of traffic load, especially at high temperature.

2.3.2 Asphalt Modifiers

Asphalt cement maybe modified by the addition of component that increase the strength of the material or otherwise alter its properties. Over years, we then evaluate and find many of the modifiers to improve the performance of asphalt. (Hunter, 2000).

2.4 Superpave Performance Grading (PG) System

In 1987, the Strategic Highway Research Program (SHRP) began developing a new system for specifying asphalt material and designing asphalt mixes. The SHRP research program produces the performance grading method for asphalt binder specification and Superpave (superior performance asphalt pavements) mix design method for asphalt concrete (Mamlouk and Zaniewski, 2006).

Extend the life or reduced the life-cycle cost of asphalt pavement represents the main objective of SHRP's research as well as reduce the maintenance costs and minimize premature failures. An important result of this research effort was the development of performance-based specification for asphalt binders and mixture to control three distress modes: rutting, fatigue cracking, and thermal cracking.

2.4.1 Performance Grade Characterization Approach

The use of performance grade tests to characterize the asphalt binders are performed at pavement temperatures to represent the lower, middle, and upper range of service temperature. The measurements are obtained at temperatures in keeping with the distress mechanisms. Therefore, unlike previous specification that requires performing the test at fixed temperature and varying the requirements for different grades of asphalt, the performance grades specification require performing the test at the critical pavement temperature and fixing the criteria for all asphalt grades. Thus, the performance grade philosophy ensures that the asphalt properties meet the specification criteria at critical pavement temperature (Mamlouk and Zaniewski, 2006).

Three pavement design temperatures are required for the binder specification: a maximum, an intermediate, and a minimum temperature. The maximum pavement design temperature is selected as the highest successive seven-day average maximum pavement temperature. The minimum pavement design temperature is the minimum pavement temperature expected over the life of the pavement. The intermediate pavement design is the average of the maximum and minimum pavement design temperature plus 4°C.

2.4.2 Asphalt Binder (Binder Course)

The intermediate paving courses of Hot Mixed Asphalt (HMA) pavement is called binder or binder courses. The classifying of grading based on viscosity and penetration has been replaced with a Performance Graded (PG) system in Superpave research. The PG system has its own nomenclature is much different than the previous asphalt cement (AC) grading system (Mamlouk and Zaniewski, 2006). The limitation of Penetration, AC Grading Systems compared to Superpave PG system and Superpave Testing and Specification Features are as follows:

i. Penetration and ductility tests are empirical and not directly related to HMA pavement performance; the physical properties measured are directly related to field performance by engineering principles.

ii. Tests are conducted at one standard temperature without regard to the climate in which the asphalt binder will be used. Test criteria remain constant, however, the temperature at which the criteria must be met changes in consideration of the binder grade selected for the prevalent climatic conditions.

iii. The range of pavement temperatures at any one site is not adequately covered. For example, there is no test method for asphalt binder stiffness at low temperatures to control thermal cracking. The entire range of pavement temperatures experienced at a particular site is covered.

iv. Test methods only consider short-term asphalt binder aging (thin film oven test) although long-term aging is a significant factor in fatigue cracking and low temperature cracking.

Asphalt binders can have significant different characteristics within the same grading category. Grading is more precise and there is less overlap between grades, Tests and specifications are intended for asphalt binders to include both modified and unmodified asphalt cements. Asphalt binder tests for Superpave performance grading are as follows:

i. Rolling thin film oven;
ii. Pressure aging vessel
iii. Dynamic shear rheometer; and
iv. Bending beam rheometer.

The PG specification uses test to measure physical properties that can be directly related to field performance by engineering principles. The (AC) system does not cover the term temperature extremes that a pavement endures. Binders that produce similar results at the temperature used for penetration and viscosity testing may have very different results at other temperatures experienced by the pavement. The performance-graded asphalt binder specifications are shown in Table 2.1 (ASTM D6373) (Mamlouk and Zaniewski, 2006).

Table 2.1: Binder Graded in the Performance Grade Specification (after Mamlouk and Zaniewski, 2006).

High Temperature Grades(°C)	Low Temperature Grades (°C)						
PG 46	-34	-40	-46				
PG 52	-10	-16	-22	-28	-34	-40	-46
PG 58	-16	-22	-28	-34	-40		
PG 64	-10	-16	-22	-28	-34	-40	
PG 70	-10	-16	-22	-28	-34	-40	
PG 76	-10	-16	-22	-28	-34		
PG 82	-10	-16	-22	-28	-34		

2.5 Superpave Mix Design

All the best effort was put it with the existing mix design methods to improve the resisting the rutting and cracking in asphalt pavements. The SHRP research program was started in 1988 in USA, and completed in 1993 and the research completed with producing the Superpave mix design and the major funds of SHRP research to establish new procedure for the selection of binder and mix design with regard to the rutting and cracking problems in asphalt pavements (Esarwi, 2008).

2.5.1 Gyratory Compactor

The equipment used in the Superpave mix design method and which is the key piece is gyratory compactor as shown in Figure 2.5 which is the principle goals of the SHRP was to develop a laboratory compaction methods, which can consistently produce specimens representative of in-service pavements. The Superpave Gyratory Compactor (SGC) compact HMA sample to densities achieved under traffic loading conditions. Its ability to estimate specimen density at any point during the compaction process is its key feature (Esarwi, 2008). Figure 2.5 shows Superpave Gyratory compactor.

Figure 2.5: Superpave gyratory compactor.

Gyratory compaction has been used in asphalt mix design since early 1900's. Midway through the SHRP, an evaluation of available gyratory compaction research was done to develop a gyratory protocol, which would simulate the density achieved at the end of pavement's life. Studies conducted during SHRP show that the density of the HMA sample is influenced mostly by the angel of gyration, and slightly by the speed of gyration and the vertical pressure. The stresses applied to the mixture and the mixture properties are the two parameters that would influence asphalt density.

2.6 Universal Testing Machine (UTM)

Operation of the machine is by hydraulic transmission of load from the test specimen to a separately housed load indicator. The hydraulic system is ideal since it replaces transmission of load through levers and knife-edges, which are prone to wear out and damage due to shock on rupture of test pieces. Load is applied by a hydrostatically lubricated ram. Main cylinder pressure is transmitted to the cylinder of the pendulum dynamometer system housed in the control panel. The cylinder of the dynamometer is also of self-lubricating design. The load transmitted to the cylinder of the dynamometer is transferred through a lever system to a pendulum. Displacement of the pendulum actuates the rack and pinion mechanism which operates the load indicator pointer and the autographic recorder. The deflection of the pendulum represents the absolute load applied on the test specimen. Return movement of the pendulum is effectively damped to absorb energy in the event of sudden breakage of specimen.

2.7 Previous Studies

Tumewu *et al.* (2005) described the evaluation of the characteristics of asphalt concrete mixtures containing Lawele natural asphalt and compared them to those normally used Kabungka natural asphalt. The type of gradations used were AC WC-2 with two different gradations, i.e. above the Fuller curve and crossing the Fuller curve between No. 4 and No. 8 sieves. 10% by weight of Lawele natural asphalt was selected to substitute the aggregates in the mixtures and pen 60/70 grade asphalt was also used. At optimum binder content, the mixtures resistance against water and temperature, resilient modulus and permanent deformation were evaluated. The performance of mixtures satisfied the requirements and showed better performance than those mixtures containing Kabungka natural asphalt.

Rudy *et al.* (2003) the results of their research showed that the use of Buton rock asphalt as fine aggregates and filler in HRA mix type C and Superpave AC mixtures, could improve its Fatigue Life, indicated by an increasing of the Effectiveness Factor, i.e. the ratio of number of cycle to failure for specimens with and without Asbuton filler, at a given stress level, ranges from 15.71 to 4.90 for HRA mix and from 521.44 to 6.38 for AC mix, depend on its stress level. The role of Asbuton filler in both asphalt mixture; HRA and AC appears also to decrease the Initial Strain, increase the Initial Stiffness (more than 300% for AC mix) and reduce the mechanism of crack initiation and crack propagation of the specimens.

Bambang *et al.* (2003) used Asbuton in their research as a fine aggregate and filler in a Hot Rolled Asphalt (HRA), according to the British Standard Specification: BS 594 part 1-1985. The results of Standard Marshall Test showed that the use of Asbuton filler will decrease the Optimum Bitumen Content and Marshall Stability, comparing to the use of "fly-ash" filler in HRA mixes. The results of Marshall Immersion test showed also the better performance of Asbuton filler (97.5% IRS), compared to "fly-ash" filler (82.5% IRS). The Wheel Tracking test gave also the same results as another test i.e. better performance of Asbuton filler (0.45 mm), compared to "fly-ash" filler (1.38 mm Do). Finally, the Resilient Modulus of HRA mix using Asbuton filler has higher value (3108MPa) than HRA mix using "fly-ash"

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